NOAA FISHERIES

Pacific Islands Fisheries Science Center

Science and Technical Approaches to Data Rich Stocks: Pacific Blue Marlin

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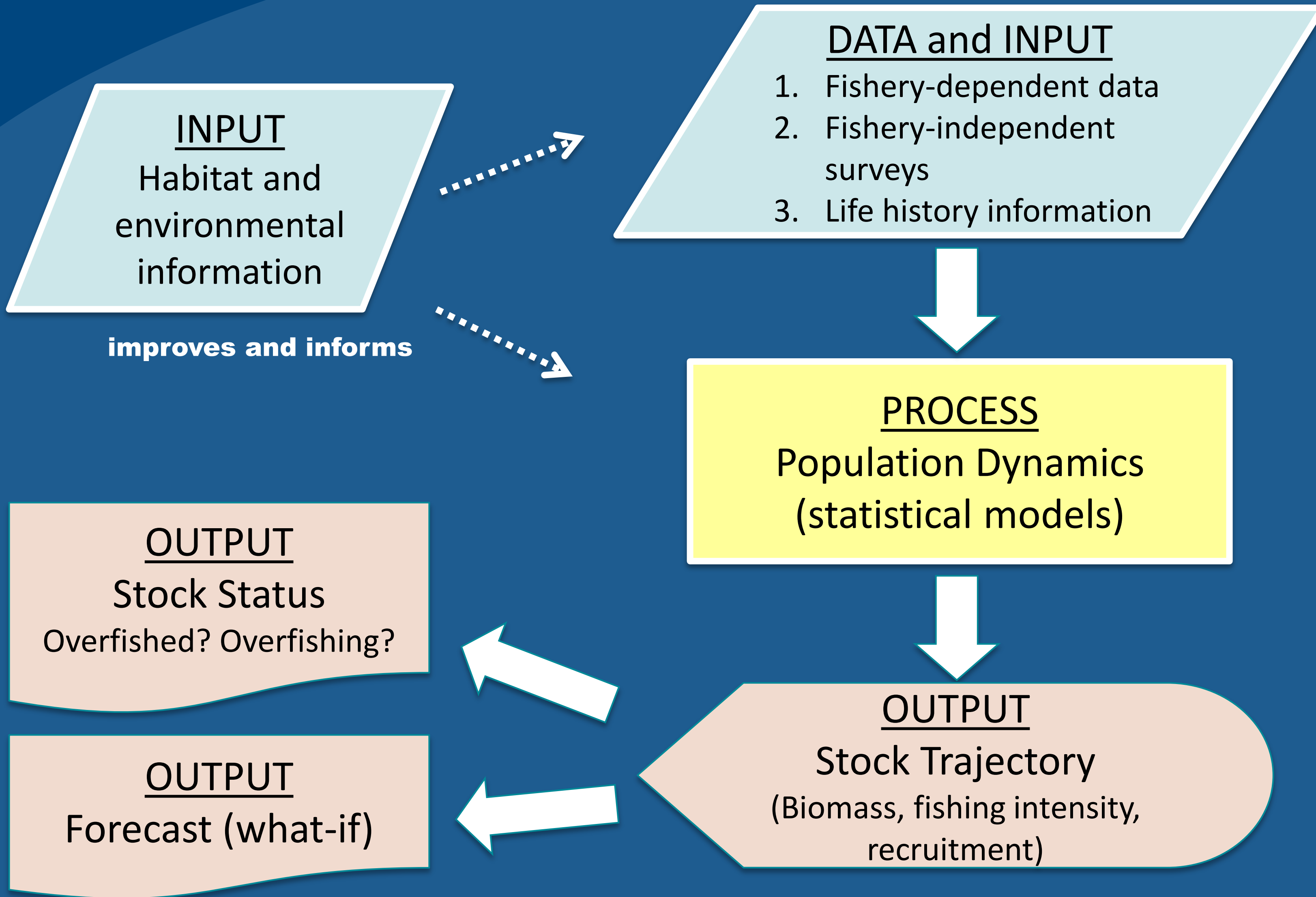
Thank FRMD leadership for supporting and reviewing the work.

Stock Assessment Process



Data and input for Pacific blue marlin

❑ Life history information

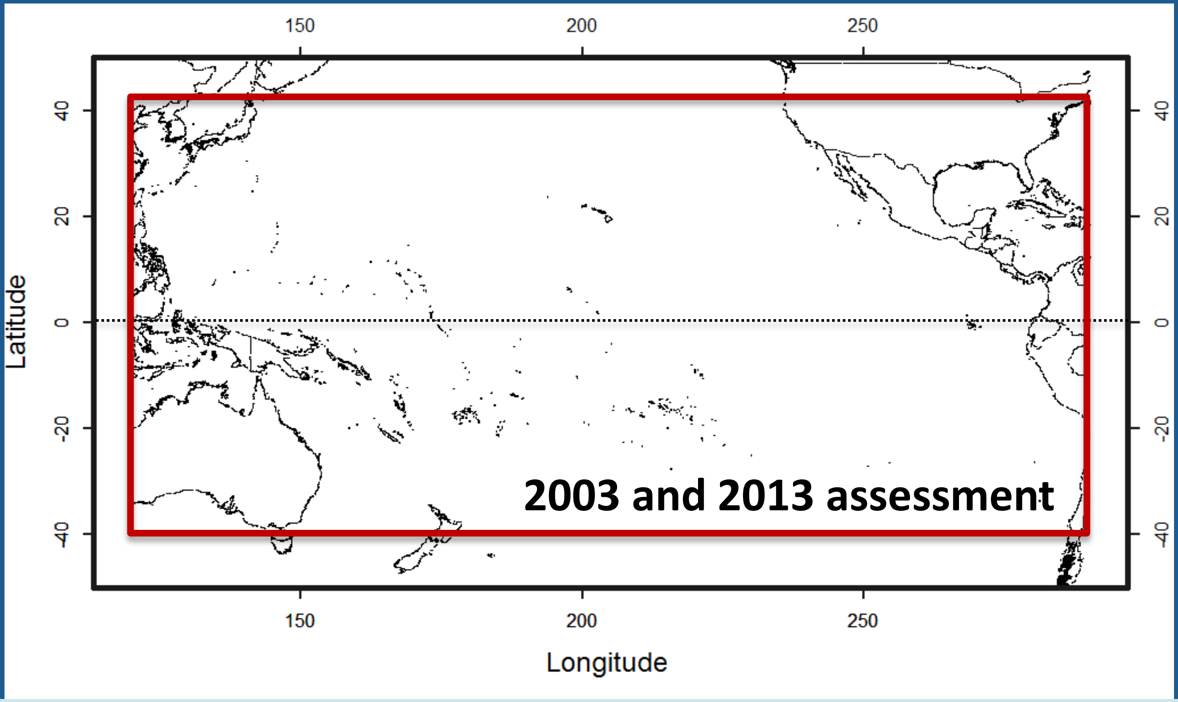
- Stock structure
- Growth
- Maturity and reproduction
- Natural morality
- Steepness

❑ Fishery-dependent data

- Catch data (commercial and recreational)
- Abundance index from catch-and-effort data (logbooks or observers)
- Size information sampled from the catch

Stock structure

- DNA-based stock structure study in 2003: there is no evidence of population structuring in the Pacific.
- All available fishery data in the Pacific were used.
- To model observations, assume that there was an instantaneous mixing of fish throughout the stock area on a quarterly basis.



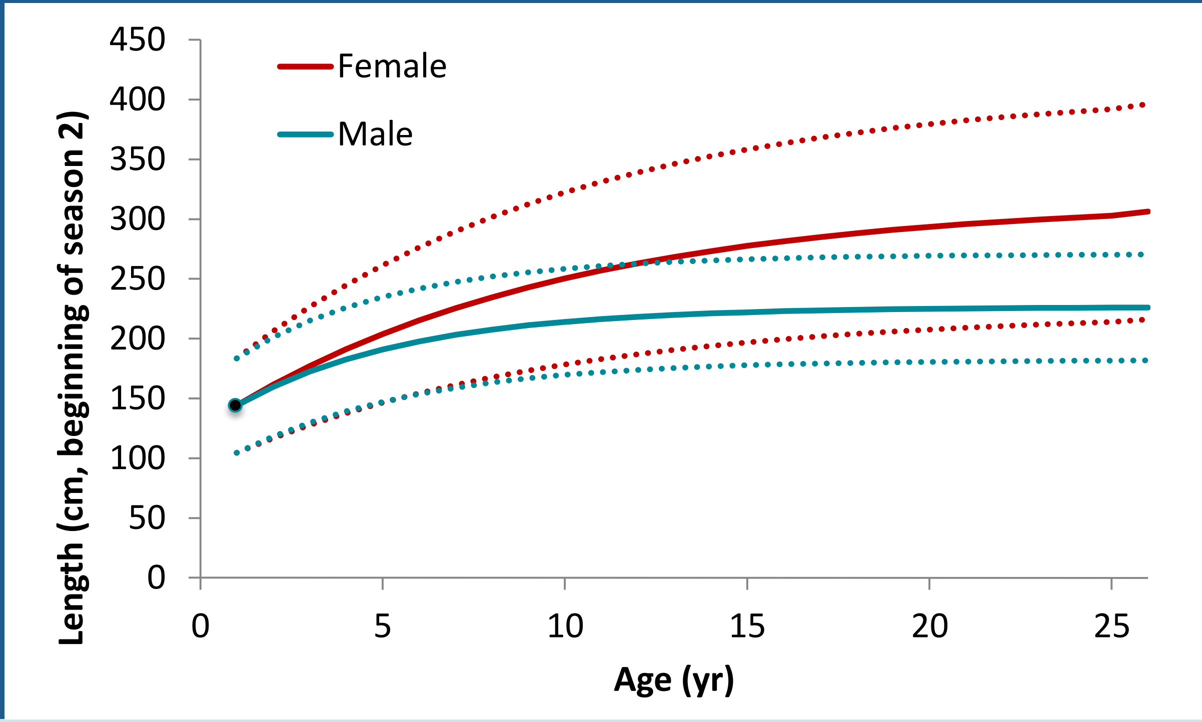
Growth

- Variability in length-at-age growth studies
- Sexual dimorphism for age >1
- Lack of otolith microstructure counts for age 0-1 and could not corroborate the first annulus

	Skillman and Yong (1976)	Hill (1986)	Chen (2001)	Dai (2002)	Shimose (2008)
Region	Hawaii waters	Hawaii waters	Taiwan waters	Taiwan waters	Japan waters
Sex-specific	Yes	Yes	Yes	Yes	Yes
Size range (EFL)	45-310 cm	95-325 cm	125-225 cm	95-240 cm	160-215 cm
Samples	length frequency data	Hard parts (Otoliths, Dorsal and Anal spines)	Hard parts (Anal spines)	length frequency data	Hard parts (Dorsal spine)

Growth

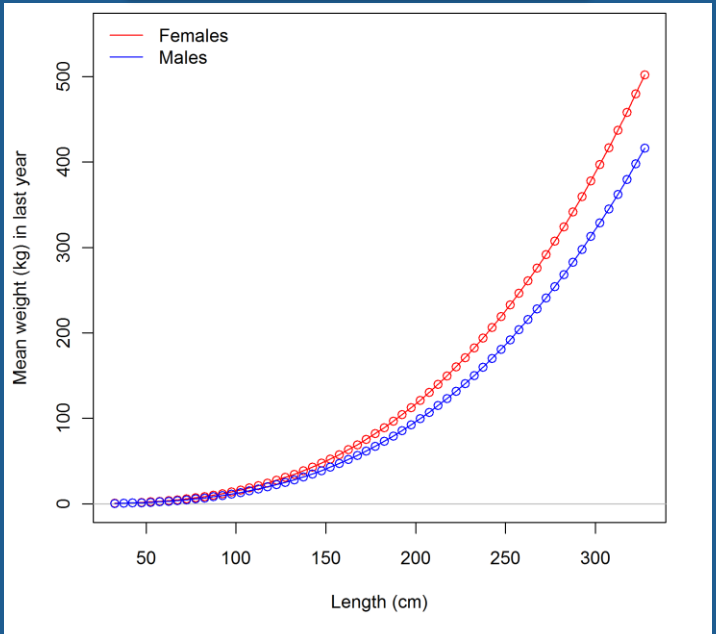
- Mean of length-at-age 1 based on Shimose's otolith daily growth increments study (no sexual dimorphism)
- Mean of length-at-age > 1 based on meta-analyses of growth studies (sexual dimorphism)



Weight- and maturity-at-length

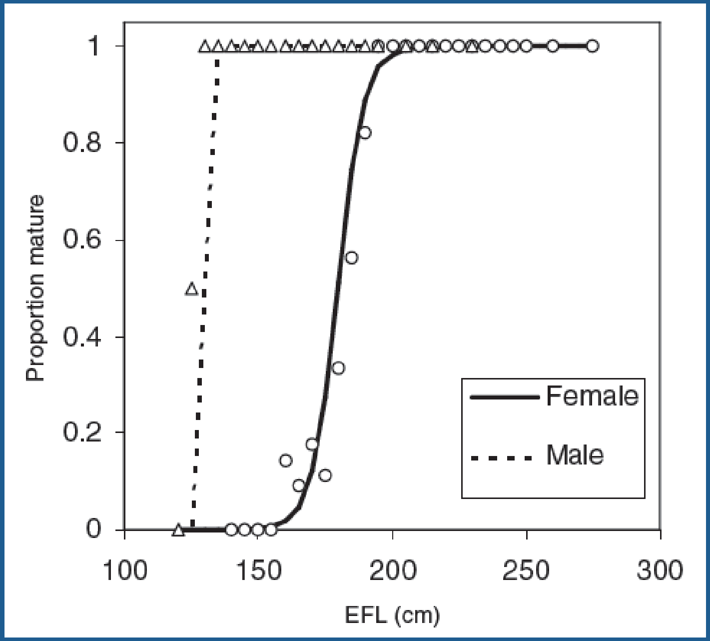
- Samples were from northwest Pacific Ocean

Weight-at-length



Meta-analysis of various studies (Brodziak 2013)

Maturity-at-length

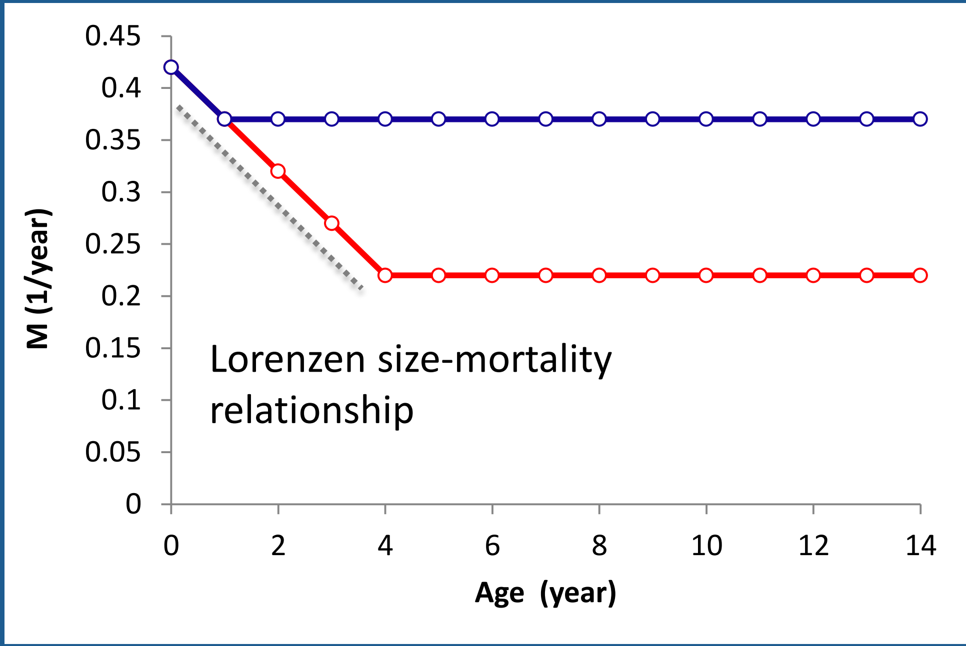


(Sun et al. 2009)

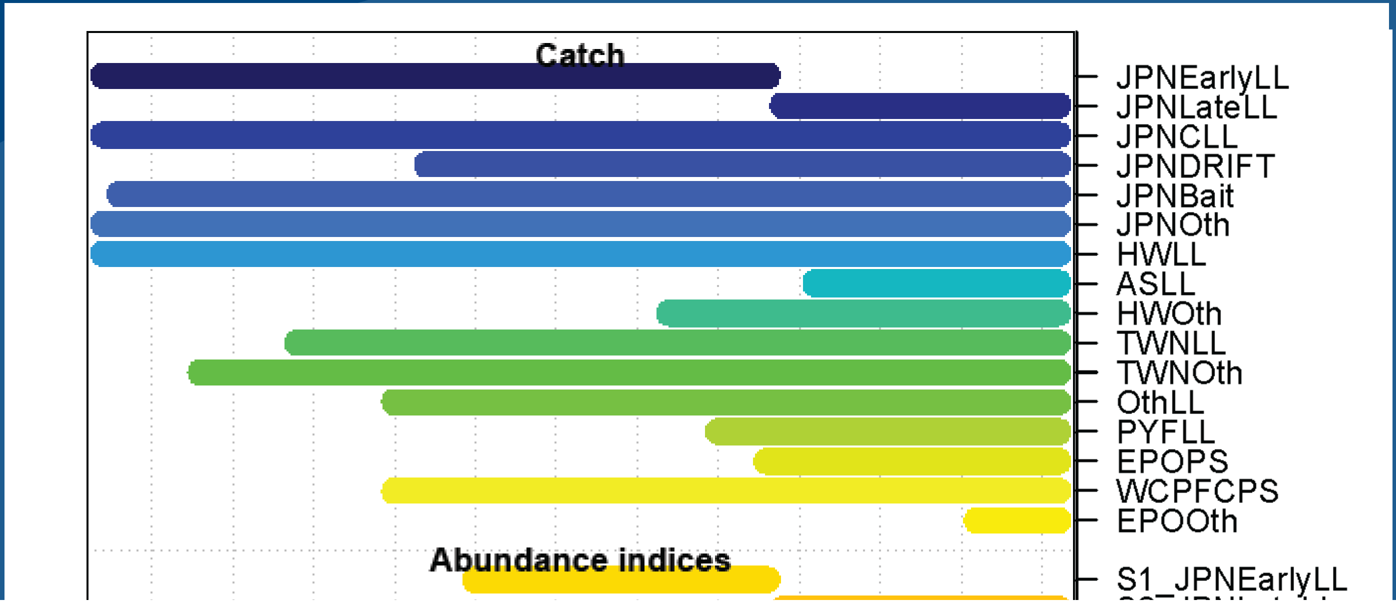
Natural mortality

- M was assumed to be age- and sex-specific.
- Meta-analysis of various indirect methods (maximum age, life history correlates, and evolutionary-ecology theory).
- Not estimated from direct methods (analyses using the actual data) (e.g. tagging data)

  - Concerns with tagging analysis: representative sampling, non-reporting of tags, tag shedding, and tag induced mortality (either initial or long-term)



Available fishery-dependent data



- Sixteen fisheries were defined on the basis of country, gear type, and reported unit of catch, which represents relatively homogeneous fishing units.

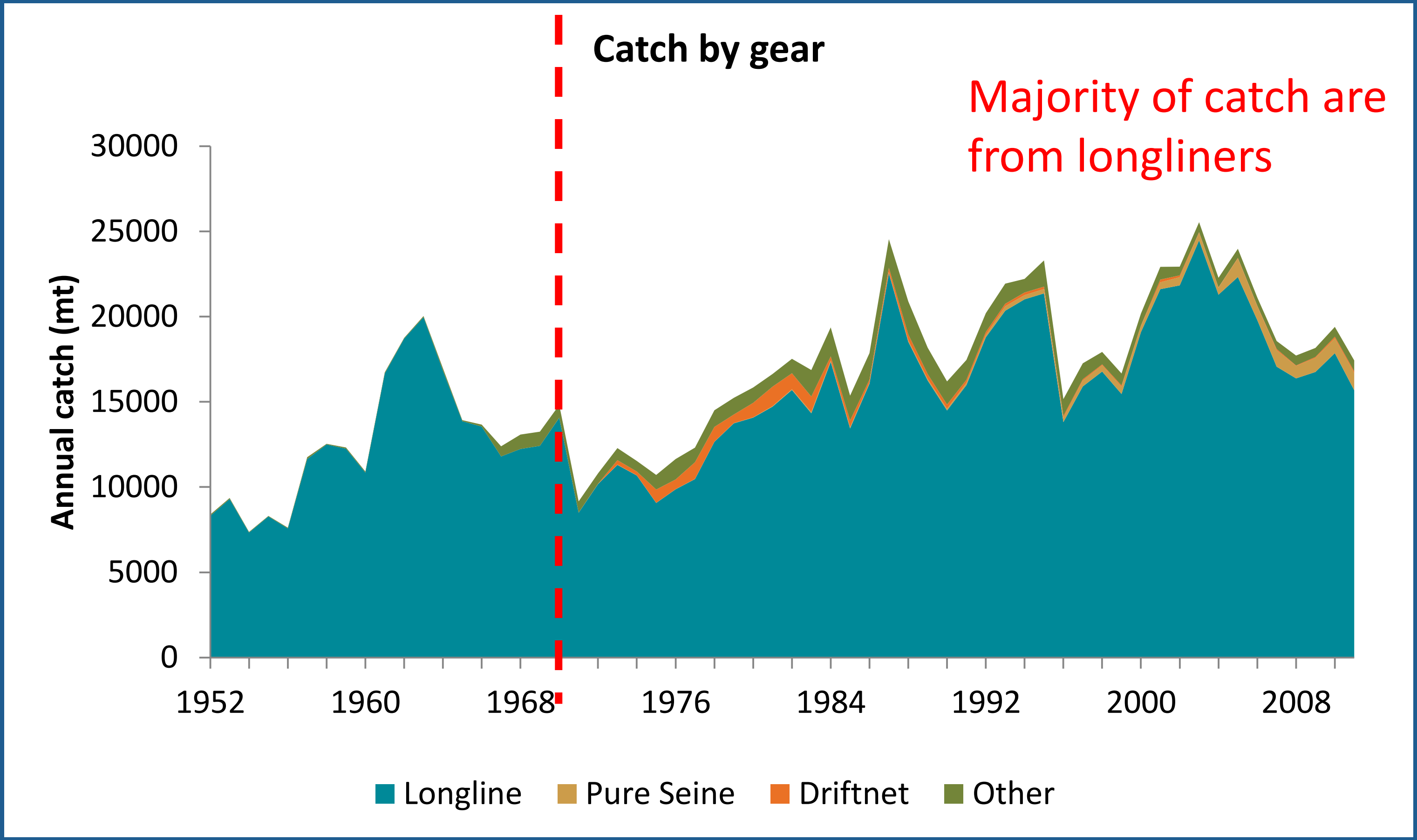
- Define fisheries in which changes in selectivity and catchability between fisheries are greater than temporal changes between years and between seasons.

Catch data

Misidentified species for Japan catch

Taiwan catch increase

Japan catch drop; Taiwan, China, and Korea catch increase



What is best available scientific information on *Catch*?

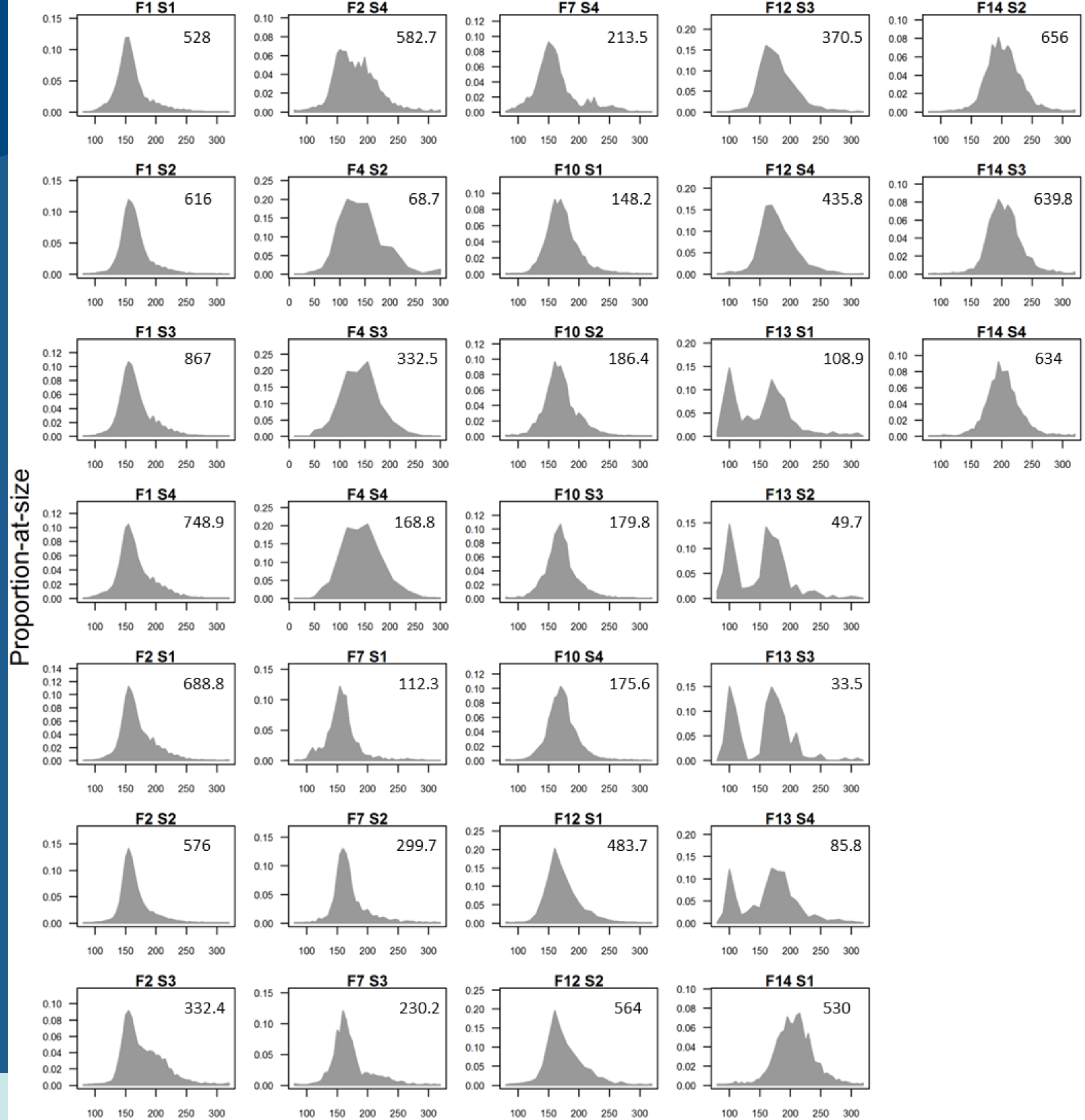
- ✓ Accurate species identification (catch is assumed to be well known)
- ✓ Characterization of uncertainty in catch reporting including discards (total removal from the fisheries)
- ✓ Spatiotemporal estimates of catch, fishing effort and size by fishing fleet and gear

Size information sampled from the catch

- Size frequency data were compiled by year, season, and fishery

	Japan LL and driftnet	Taiwan LL	Hawaii LL	Various flags LL	EPO PS
What is measurement precision?	nearest 1 or 5 cm or nearest 1 kg	nearest 2 cm	nearest 1 cm	nearest 2 cm	nearest 1 mm
How was the measurement taken?	landing ports by samplers or onboard measure by crew	onboard measure by crew	onboard measure by observer	landing ports by samplers or onboard measure	onboard measure by observer
Sampling design	Sample first 30 fish	Sample first 30 fish	Sample from every 3rd fish	Not available	Sample first 50 fish
Spatial coverage	Pacific	Pacific	Hawaii waters	Pacific	eastern Pacific

- EFL (cm) or processed weight (kg)
- Size data were not identified to gender



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Abundance index from catch-and-effort data

- Catch and effort data were compiled by fishery and used to develop standardized annual indices of relative abundance by the ISC members .

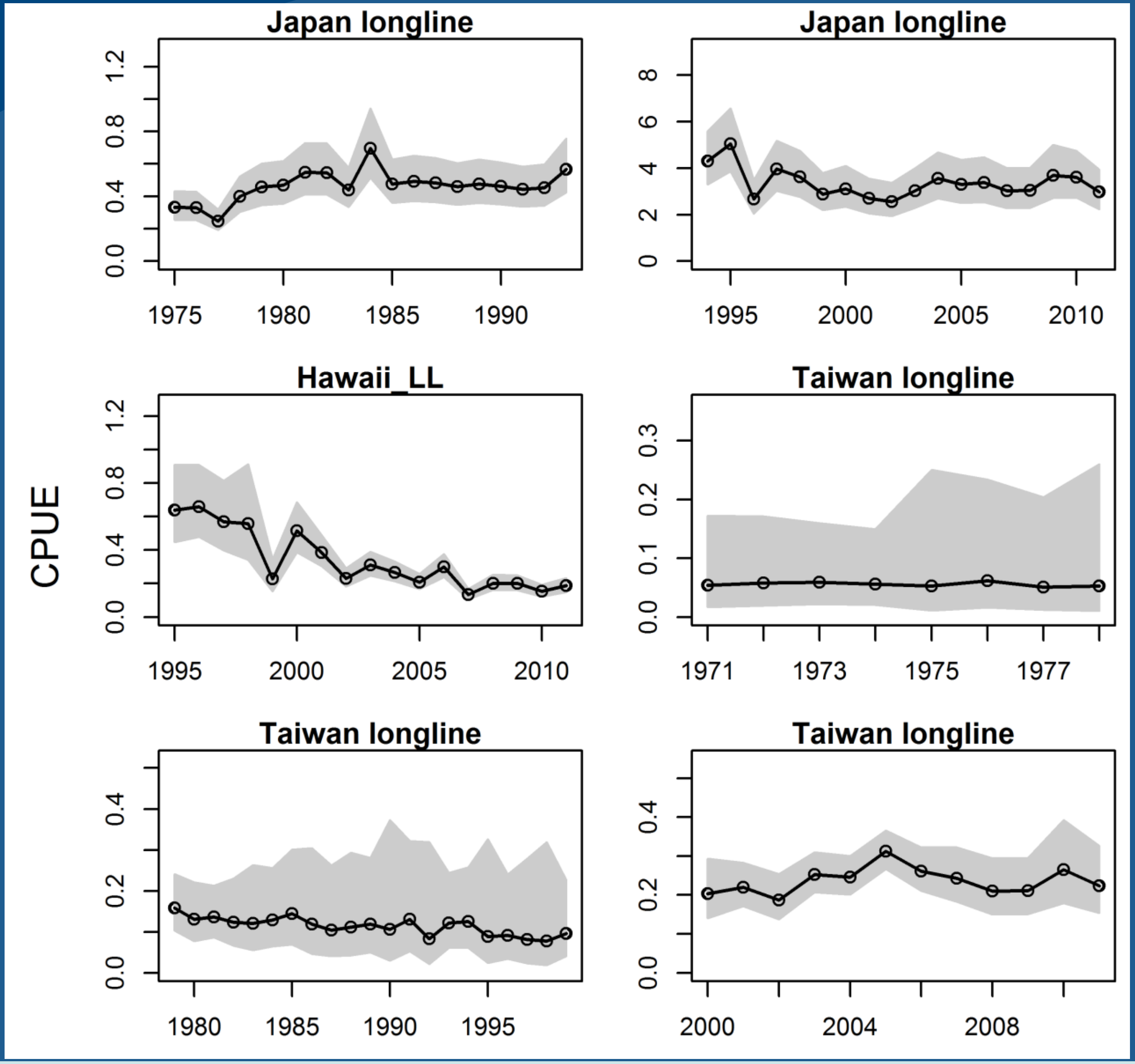
	Japan LL	Taiwan LL	Hawaii LL
Data resolution (time-area strata)	Operational, 5X5 degree	Aggregated monthly, 5X5 degree	Operational, 1X1 degree
Source	Catch and effort data (Logbook)	Raised catch and effort data (Category II)	Observer
Spatial coverage	Pacific	Pacific	Hawaii waters

Abundance index from catch-and-effort data

Delta GLM

Delta GLM

GAM



Habitat-based standardization

GAM

GAM

What is best available scientific information on *CPUE standardizations?*

- ✓ Fishery descriptions including history of fishery development and changes
- ✓ Describe data selection, CPUE standardization model, and CPUE estimates
- ✓ Provide model diagnostics and goodness of fit criteria relative to alternative model configurations
- ✓ Compare nominal and standardized CPUE
- ✓ Characterize uncertainty in estimates of standardized CPUE

Stock Assessment Process

INPUT
Habitat and environmental information

improves and informs

DATA and INPUT

1. Fishery-dependent data
2. Fishery-independent surveys
3. Life history information

PROCESS
Population Dynamics (statistical models)

OUTPUT
Stock Trajectory
(Biomass, fishing intensity, recruitment)

OUTPUT
Stock Status
Overfished? Overfishing?

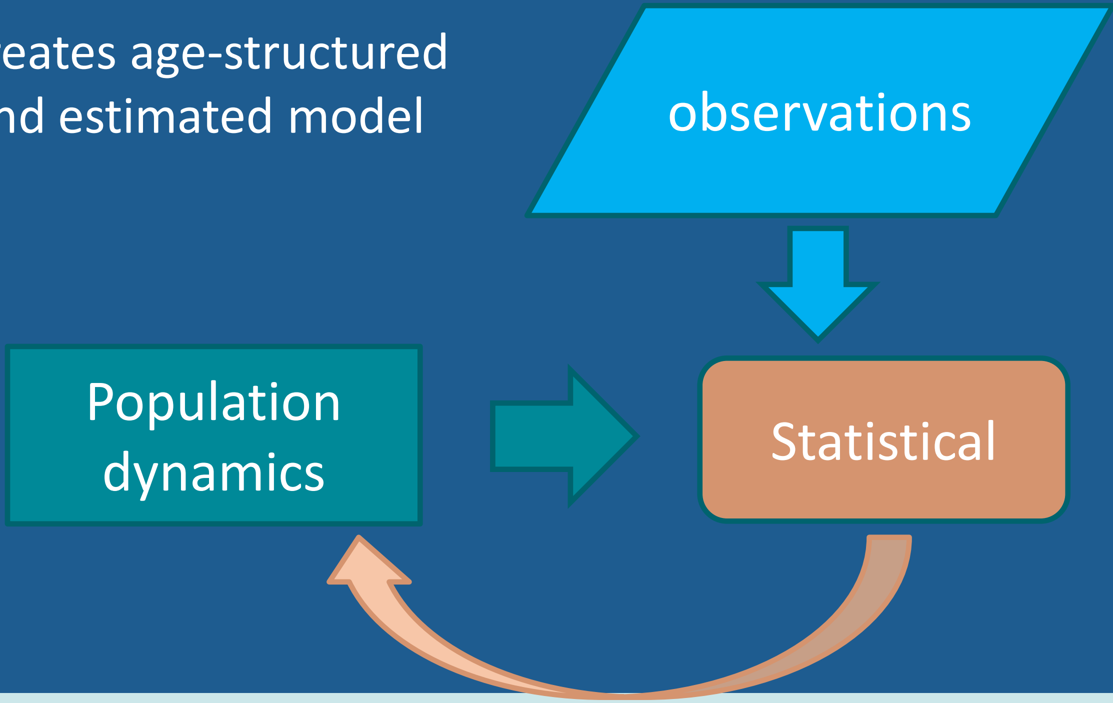
OUTPUT
Forecast (what-if)

Integrated assessment model

1) an observational component that consists of the observed data such as catch or length/age composition,

2) a statistical component that quantifies the fit of model predictions to the data using a negative log-likelihood function,

3) a population component that creates age-structured population dynamics using fixed and estimated model processes.



Stock Synthesis Version 3.24f

Life history information

Parameter (unit)	Value	Estimated
natural mortality (M, age-specific^{-yr})	female: 0.42-0.22 male: 0.42-0.37	fixed
length_at_1 yr (EFL cm)	female: 144 male: 144	fixed
length_at_26 yr (EFL cm)	female: 304.178 male: 226	fixed
VonBert_K	female: 0.107 male: 0.211	fixed
$w=aL^b$ (kg)	female: 1.844E-05, 2.956 male: 1.37E-05, 2.975	fixed
Size at 50-percent-maturity (EFL cm)	female: 179.76	fixed

Recruitment parameters

Parameter (unit)	Value	Estimated
Spawning season	2	fixed
Recruitment season	2	fixed (best model fit to age-0 fish fisheries)
spawner-recruit steepness (h)	0.87	fixed (Beverton and Holt SR model; borrowed from striped marlin)
unfished Recruitment Ln(R0)		estimated
standard deviation of recruitment	0.32	fixed (iteratively rescaled to match the expected variability)
recruitment deviations	1971-2010	estimated
initial age structure	5 years	estimated

Little information on recruitment extends more than 5 yrs explained by the fast growth before they mature around age 3.

Fishery dynamic process

- Two processes are used to describe the fishery dynamics:

  - Selectivity is used to characterize age/length-specific pattern for the fishery.

    - Estimate selectivity for each fishery as a function of size.

    - Because size data were not identified to gender, assume that same size of fish from female and male is equally selected by fisheries in a well-mixed ocean.

    - In single area model, selectivity pattern is a combination of gear/operations effects and spatial distribution of the population.

  - Catchability is used to scale vulnerable biomass.

    - Assume to be constant over time for all indices

Fishery dynamic process

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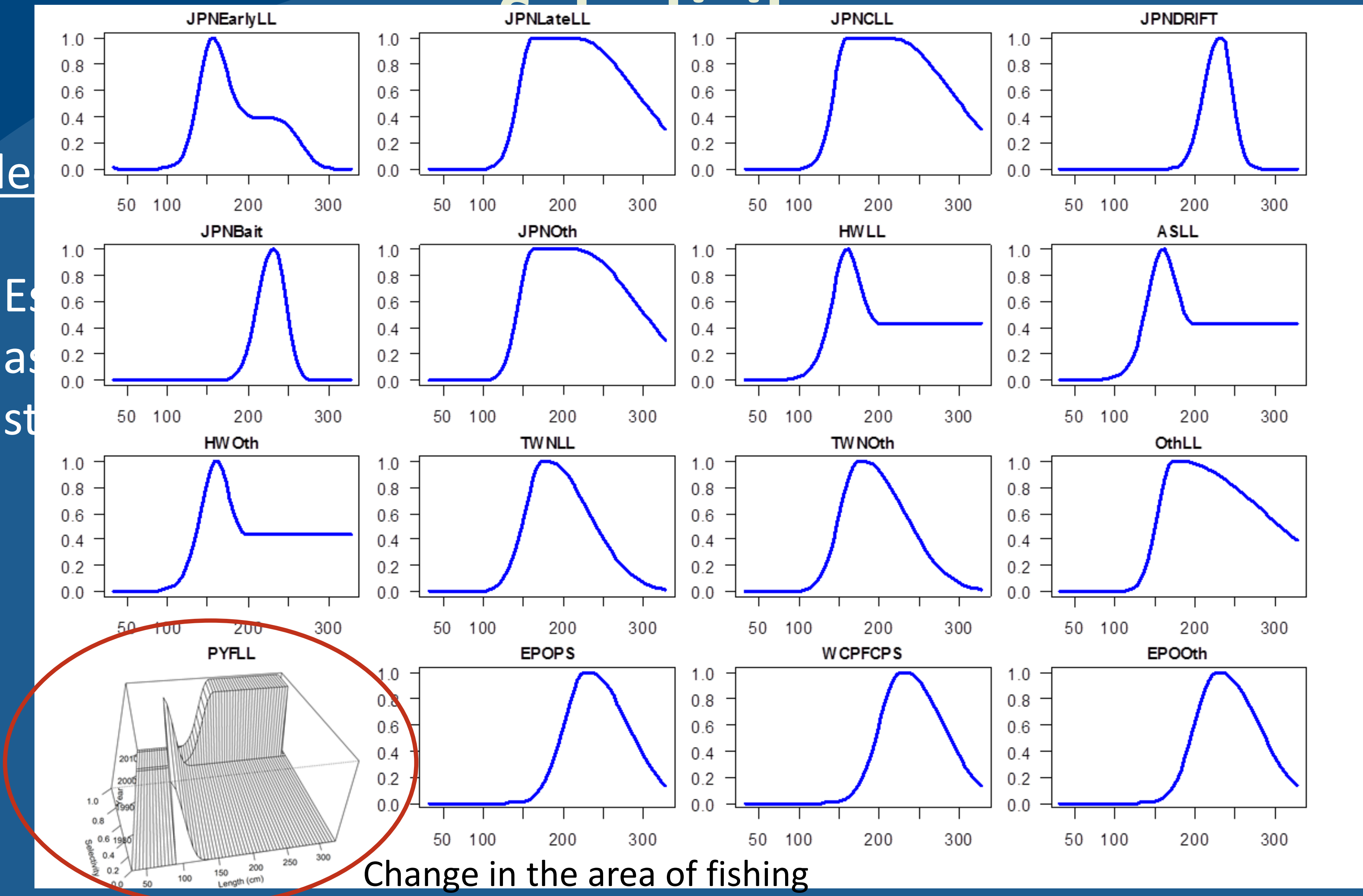


Change in the area of fishing

Statistical component
Catch, CPUE, Size

- Observed catch data were assumed to be
  - unbiased and precise,
  - a lognormal with a SE= 0.05 reflecting high precision.

- CPUE indices were assumed to be
  - lognormal with annual CPUE and SE from the standardization analyses.

- Size composition data were assumed to be
  - multinomial with variance described by the estimated effective sample size.

Selection among CPUEs

- An abundance data set is representative of stock abundance/trend

- When series are in conflict with other representative series:
  Francis (2011) proposed-
  Provide alternative assessments
  (two groups: A - the data set is consistent; or B - it is not)

- If we simply downweight the inconsistent data set we will produce a result that lies somewhere between these two assessments. This result will be wrong in case A, and it will be wrong in case B.

Selection among CPUEs

Correlation matrix

	JP LL1	JP LL2	HW LL	TW LL1	TW LL2	TW LL3
JPLL1 (1975-1993)		0	0	4	15	0
JPLL2 (1994-2011)	NA		17	0	6	12
HWLL (1995-2011)	NA	0.36		0	5	12
TWLL1 (1971-1978)	0.20	NA	NA		0	0
TWLL2 (1979-1999)	0.15	0.15	**-0.48**	NA		0
TWLL3 (2000-2011)	NA	**0.46**	-0.27	NA	NA	

Down-weighting analyses

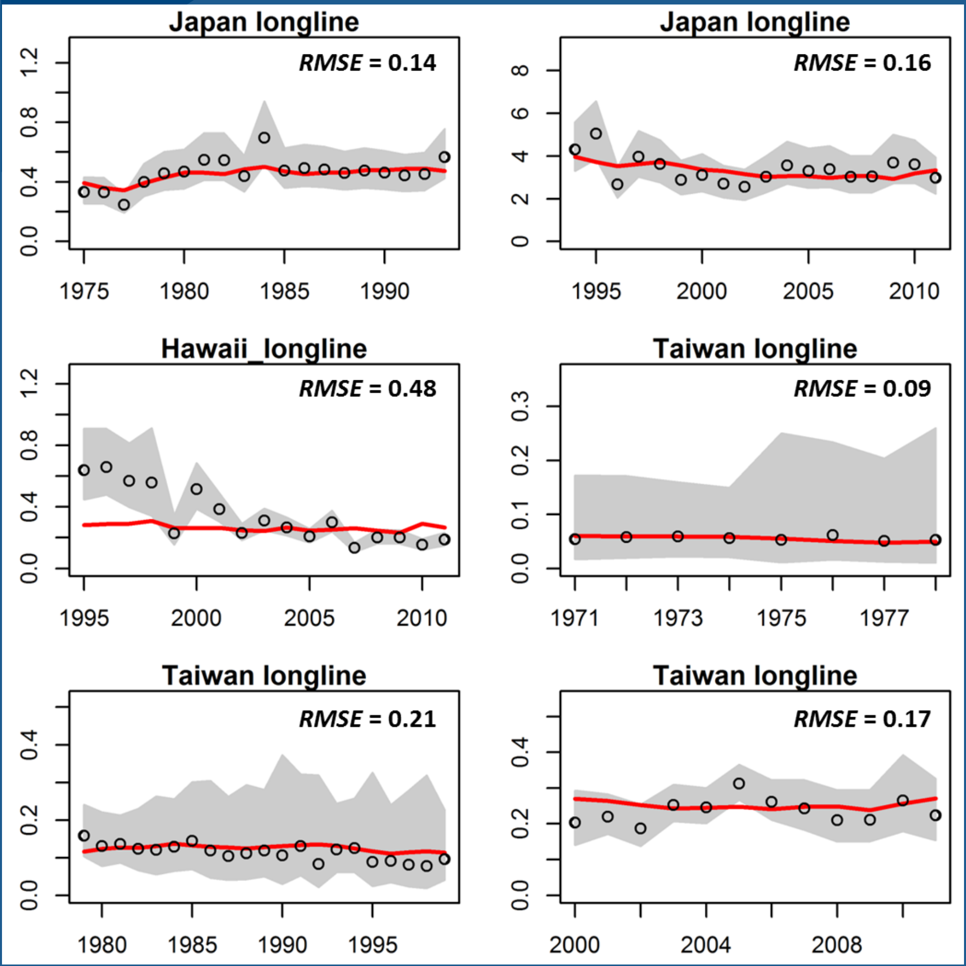
	JP LL1	JP LL2	HW LL	TW LL1	TW LL2	TW LL3
DW JPLL			-13.2	0.0	-0.6	6.6
DW HWLL	0.0	-11.6		0.0	-0.1	-4.0
DW TWLL	0.0	5.4	-5.1			

A negative value - better fit

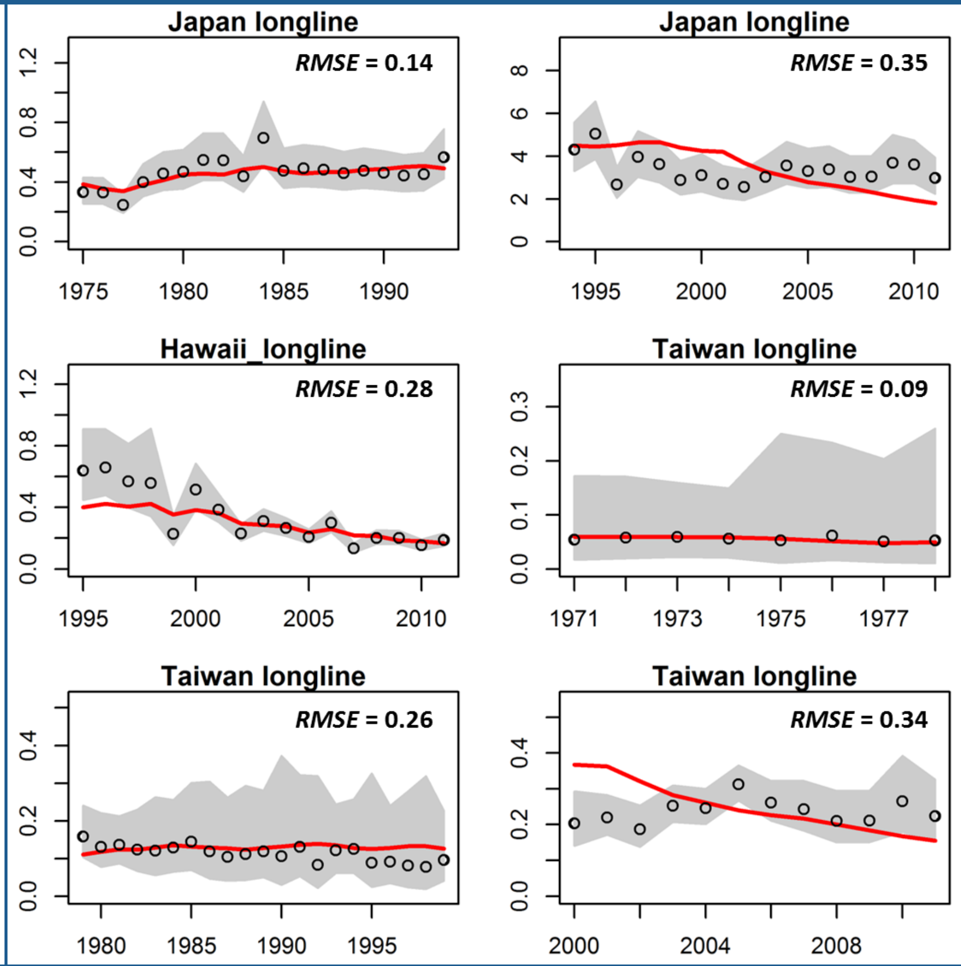
- Two different population trajectories:
  - Group A: JPN_LL and TW_LL
  - Group B: JPN_LL1 and HW_LL

Selection among CPUEs

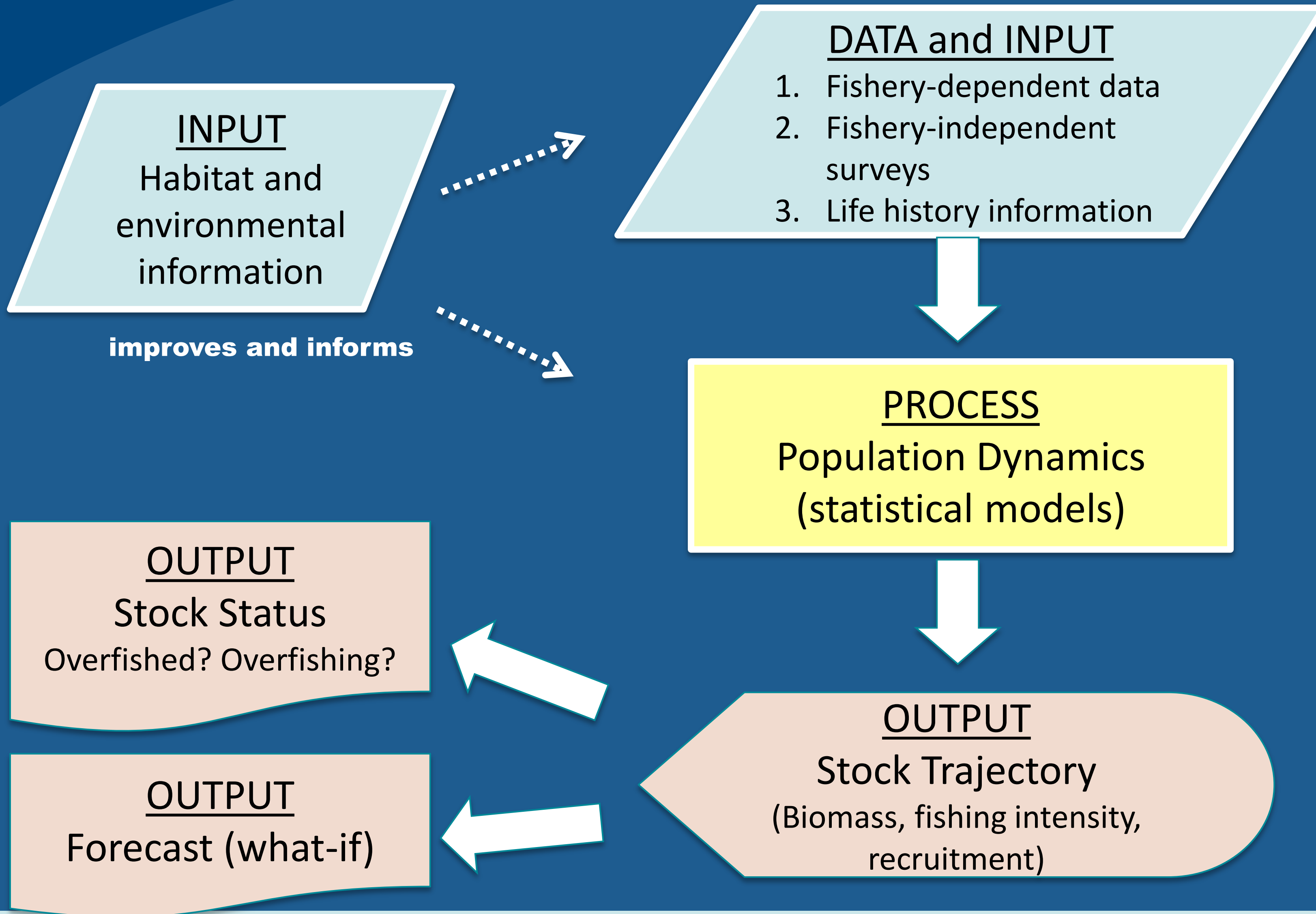
Group A



Group B



Stock Assessment Process



Model checking

Convergence

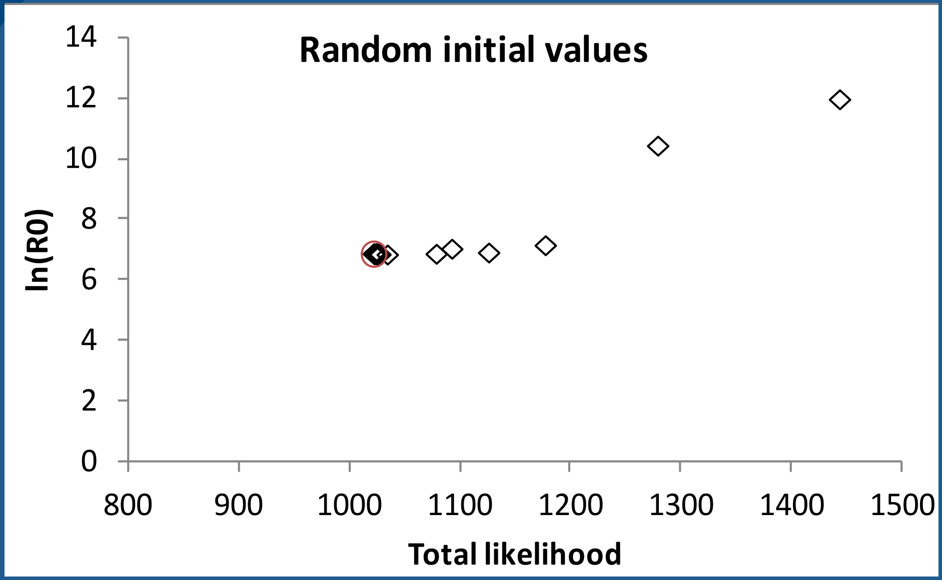
- No evidence of a lack of convergence as
  - Hessian was positive-definite,
  - Variance-covariance matrix was estimable,
  - Correlation coefficients between parameters were acceptably low.

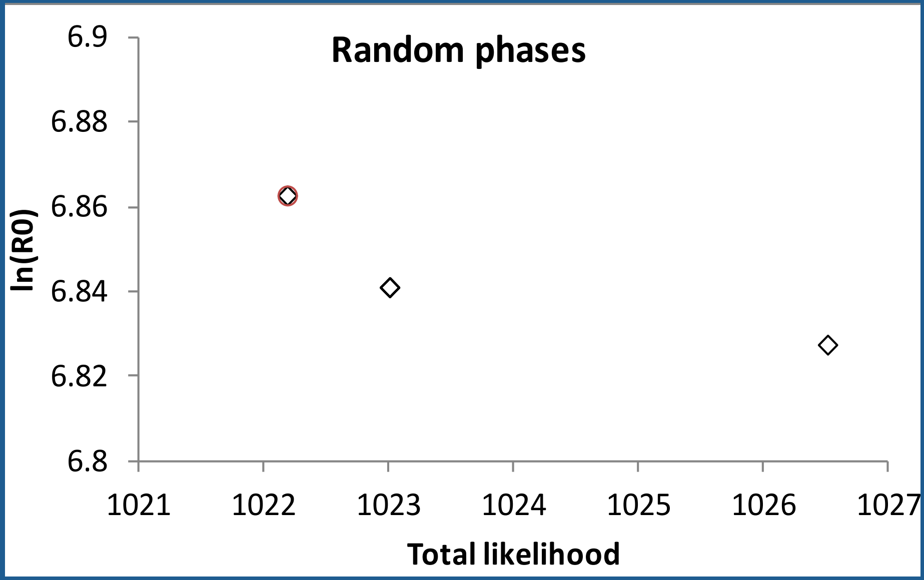
Diagnostics

- Randomly perturbing the parameter starting values and phases of parameters
- Goodness of fit: residuals analysis
- Likelihood profile of virgin recruitment
- Retrospective analysis

Model diagnostics

- Randomly perturbing the parameter starting values and phases of parameters



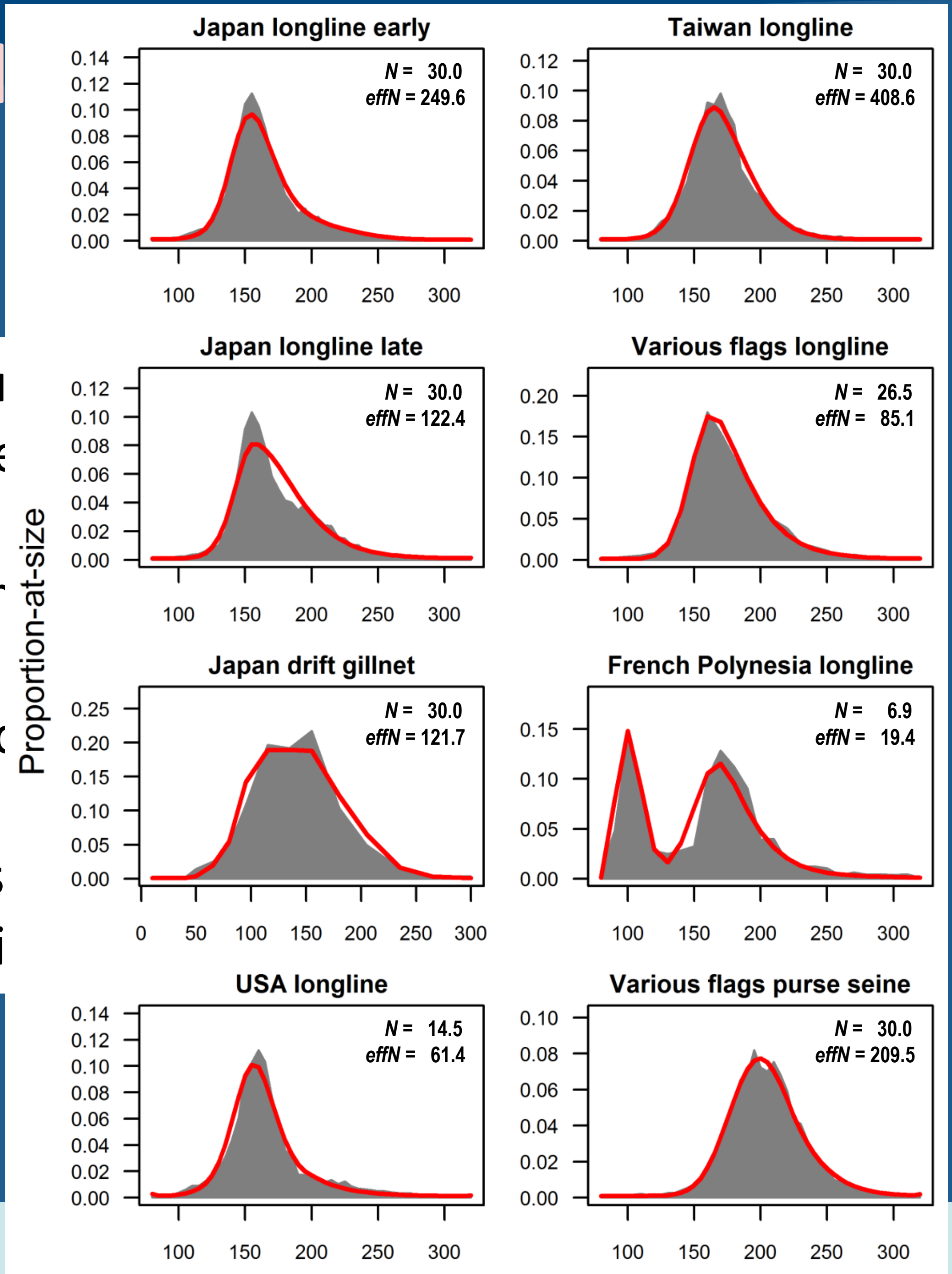


We could not find a better fitting model.

Model

❑ Goodness of fit

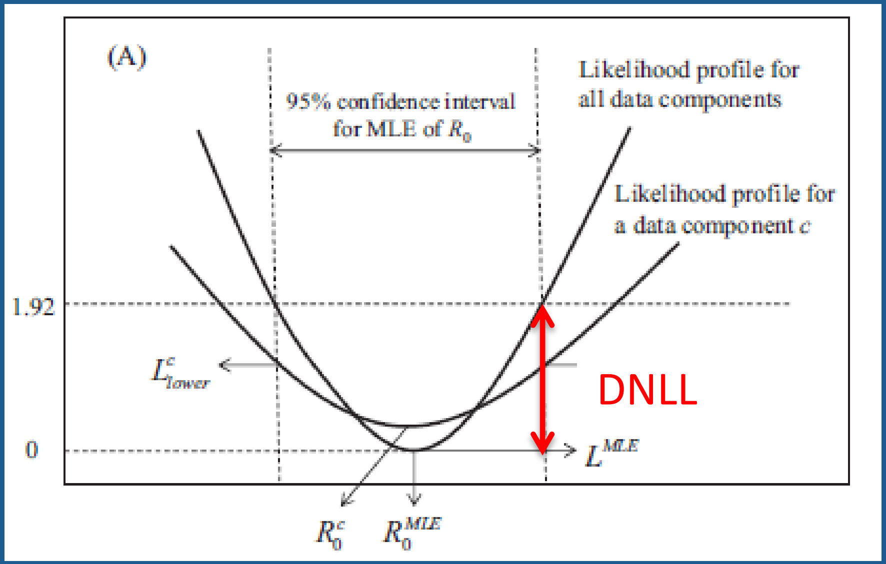
- Predicted catch data were u
  model removed >99% of the
- The model represented trer
  abundance reasonably well
  confidence intervals of the c
- Predicted size compositions
  the observed size compositi

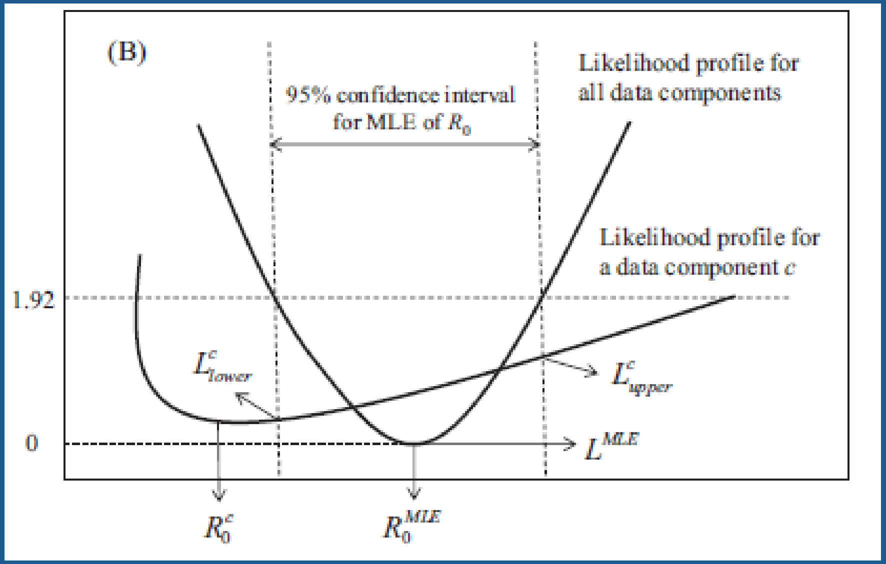


Model diagnostics

- Likelihood profile of virgin recruitment (R_0)
  - the degradation in model fit (DNLL: NLL - the minimum of NLL)

1. Identify how much information there is on scaling from that component
2. Identify where conflicts in the data occur





Wang et al. 2014

Model diagnostics

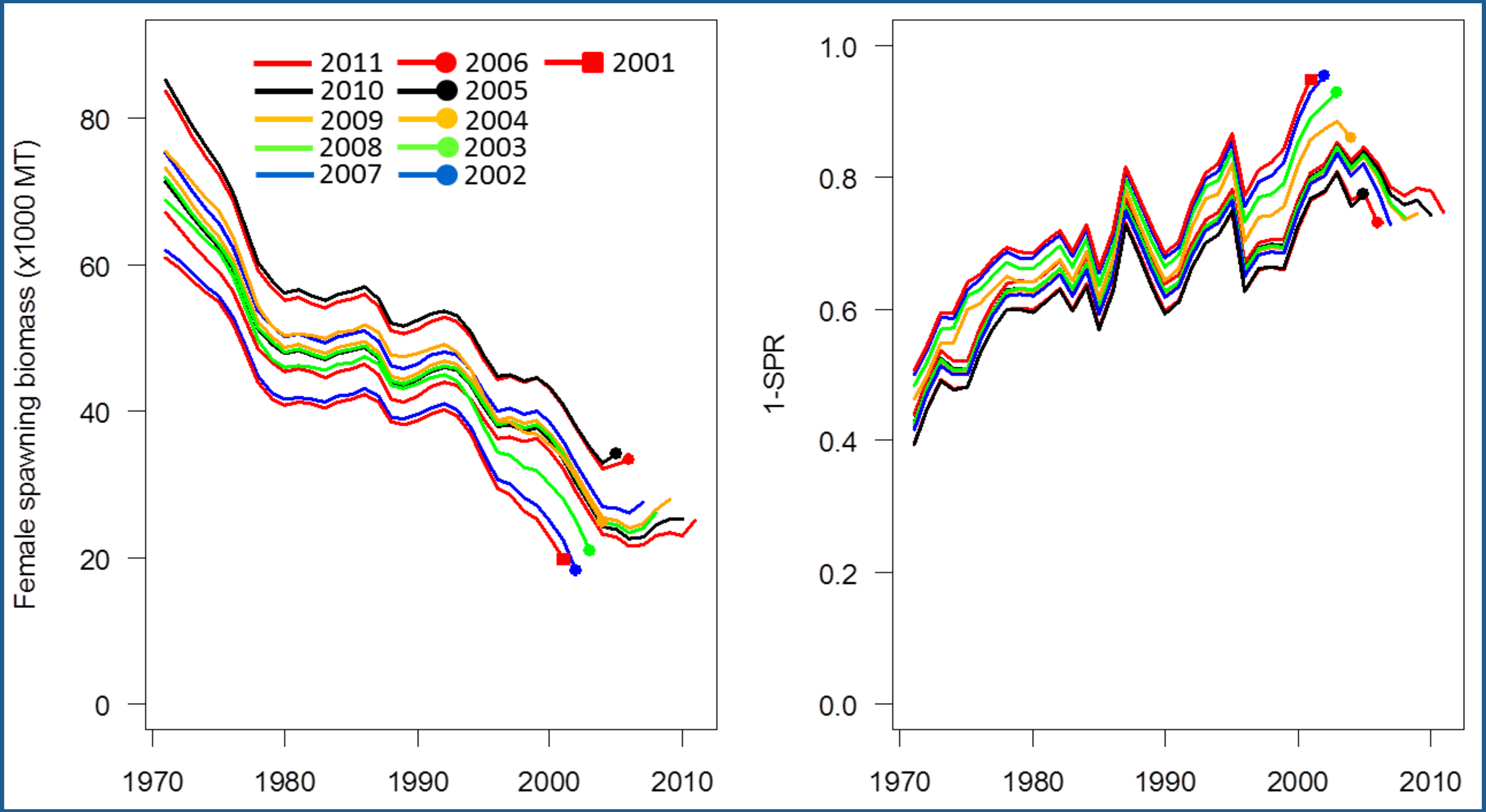
- Likelihood profile of virgin recruitment (R_0)

Estimate of ln(R_0)	ln(R_0)	Composition data components								Index data components					
		F1	F2	F4	F7	F10	F12	F13	F14	S1	S2	S3	S4	S5	S6
(6.86)	6.5	8	7	0	3	0	0	2	1	2	7	0	0	2	1
	6.6	4	4	0	3	0	0	1	1	0	6	0	0	1	1
	6.7	0	1	0	3	0	1	1	0	0	4	0	0	1	0
	6.8	0	0	0	2	0	2	0	0	1	2	0	0	1	0
	6.9	1	1	0	1	0	3	0	1	1	1	0	0	0	0
	7.0	1	3	1	0	1	4	0	2	2	0	0	0	0	0
	7.1	1	4	1	0	1	5	1	3	2	0	0	0	0	0

- Internally consistent model regarding scale where composition component DNLL <3 units and index component DNLL<2 units at the R_0 when estimated

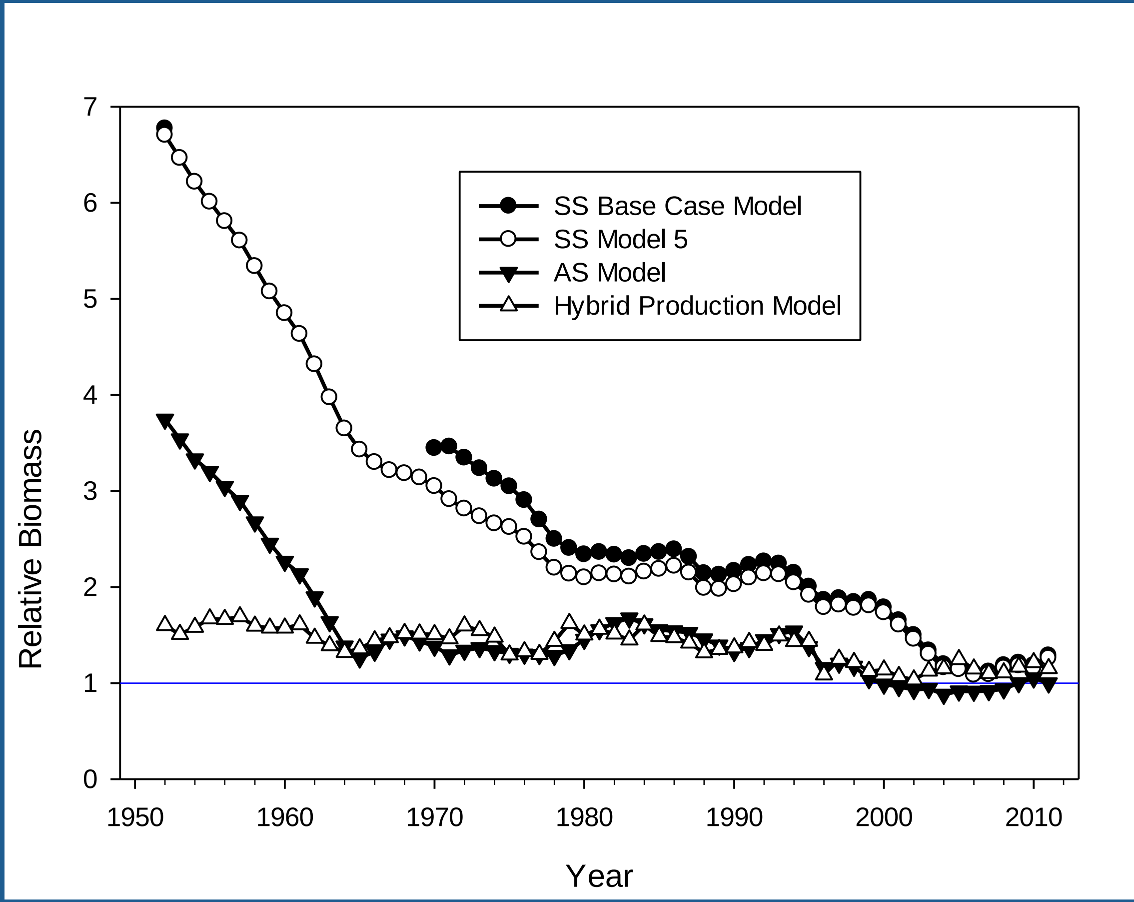
Model diagnostics

- Retrospective analysis



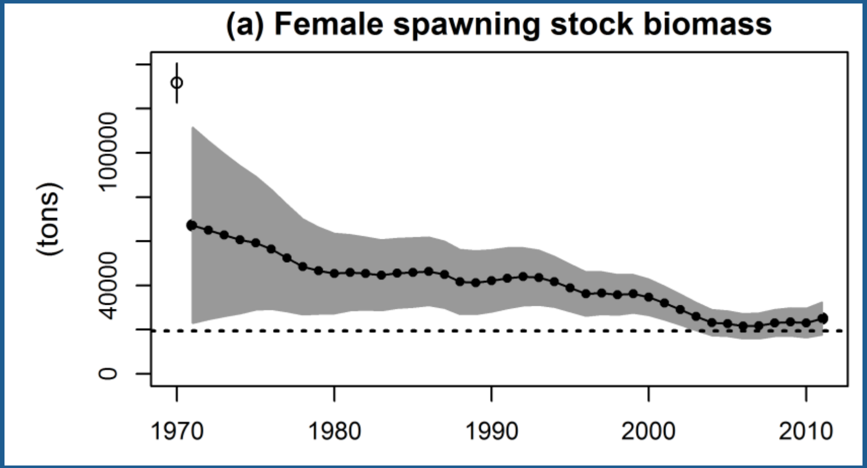
Compare to alternative models

- SS model 5 and AS model: relative biomass declined by 50% during the first 10 years.
- A hybrid production model: relative biomass showed a less decline.
- Results from each of the alternative models were similar at the end of the time series, showing the robustness of the assessment results.

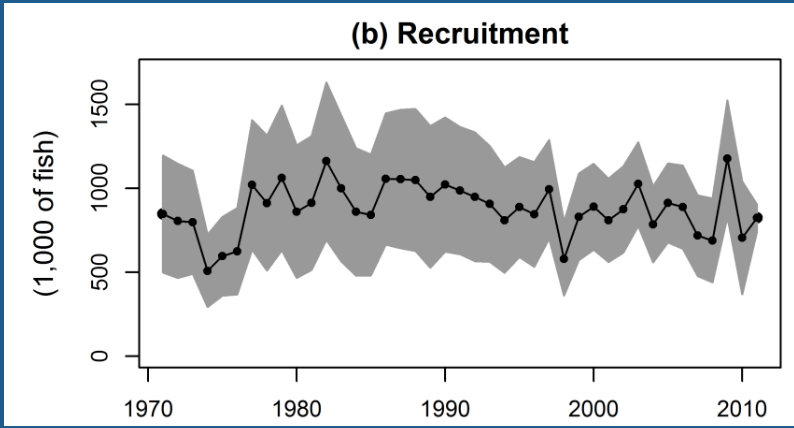


Stock trajectory

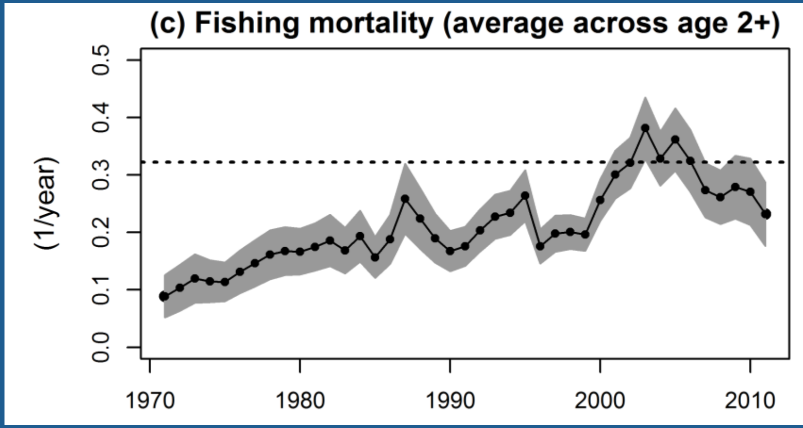
- Estimates of spawning biomass declined from the 1970s through the early 2000’s, before stabilizing in the last few years.



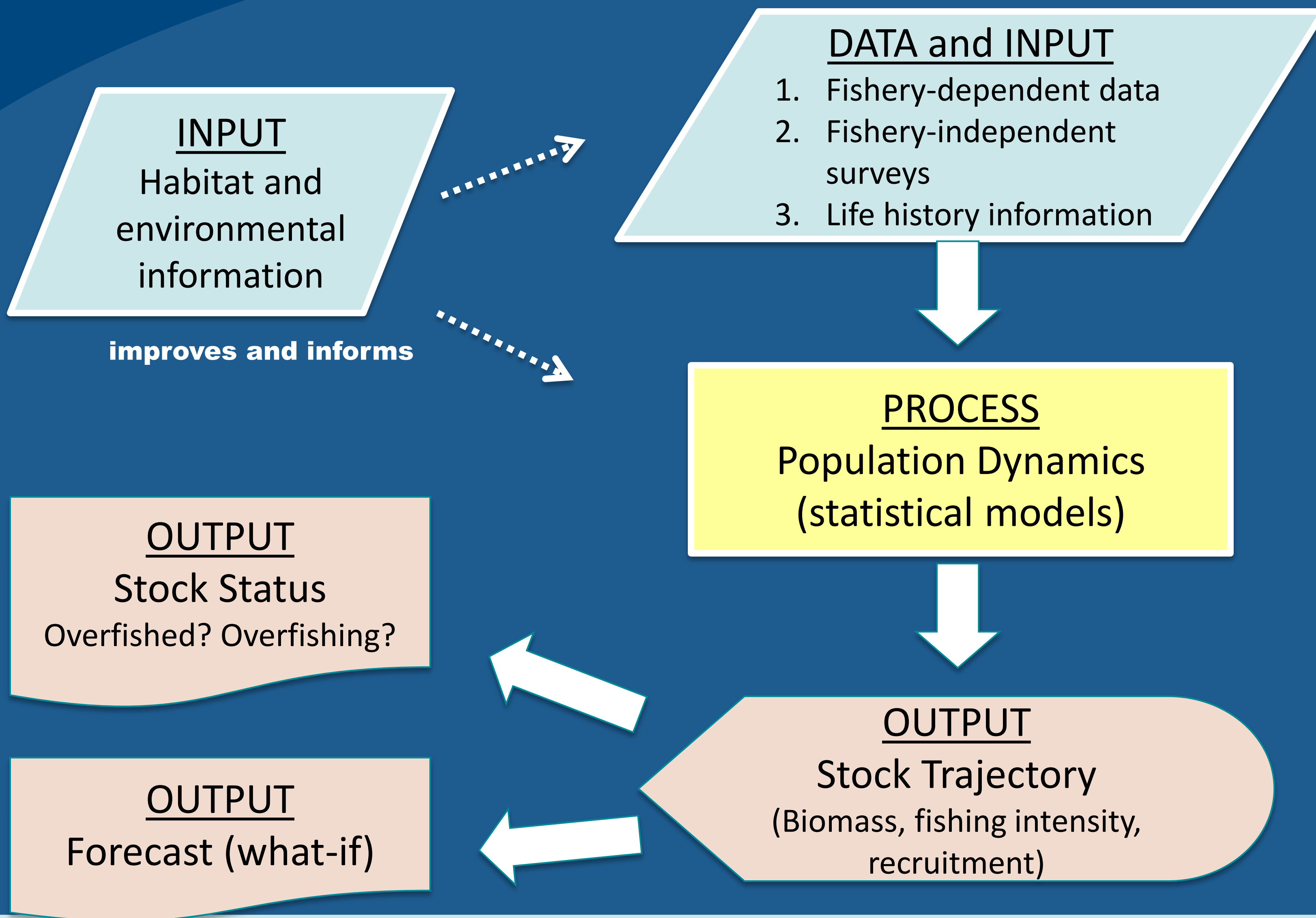
- Recruitment levels remained relatively stable.



- Estimated fishing mortality increased from 1971 to 2003, thereafter declining.

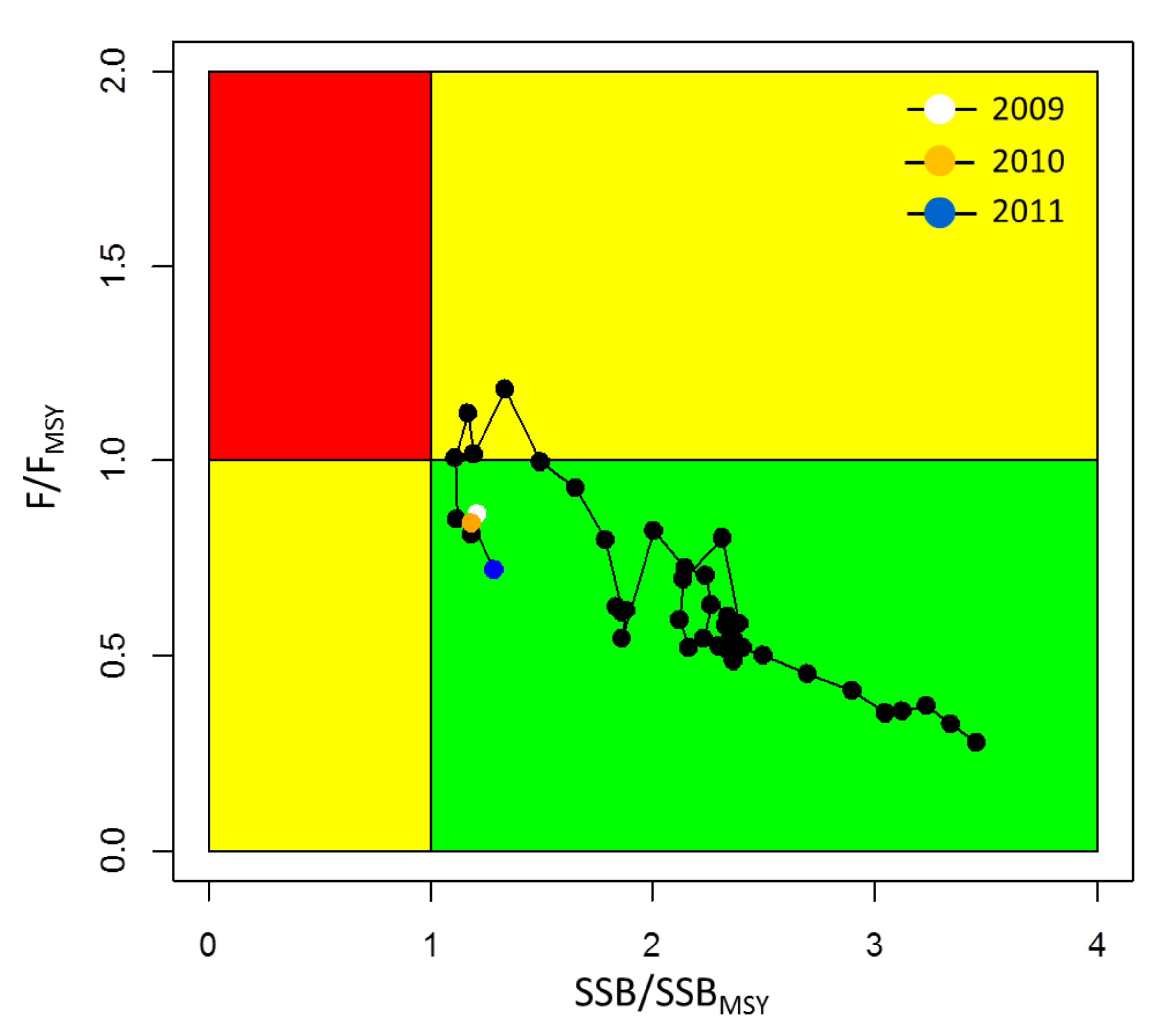


Stock Assessment Process



Stock status

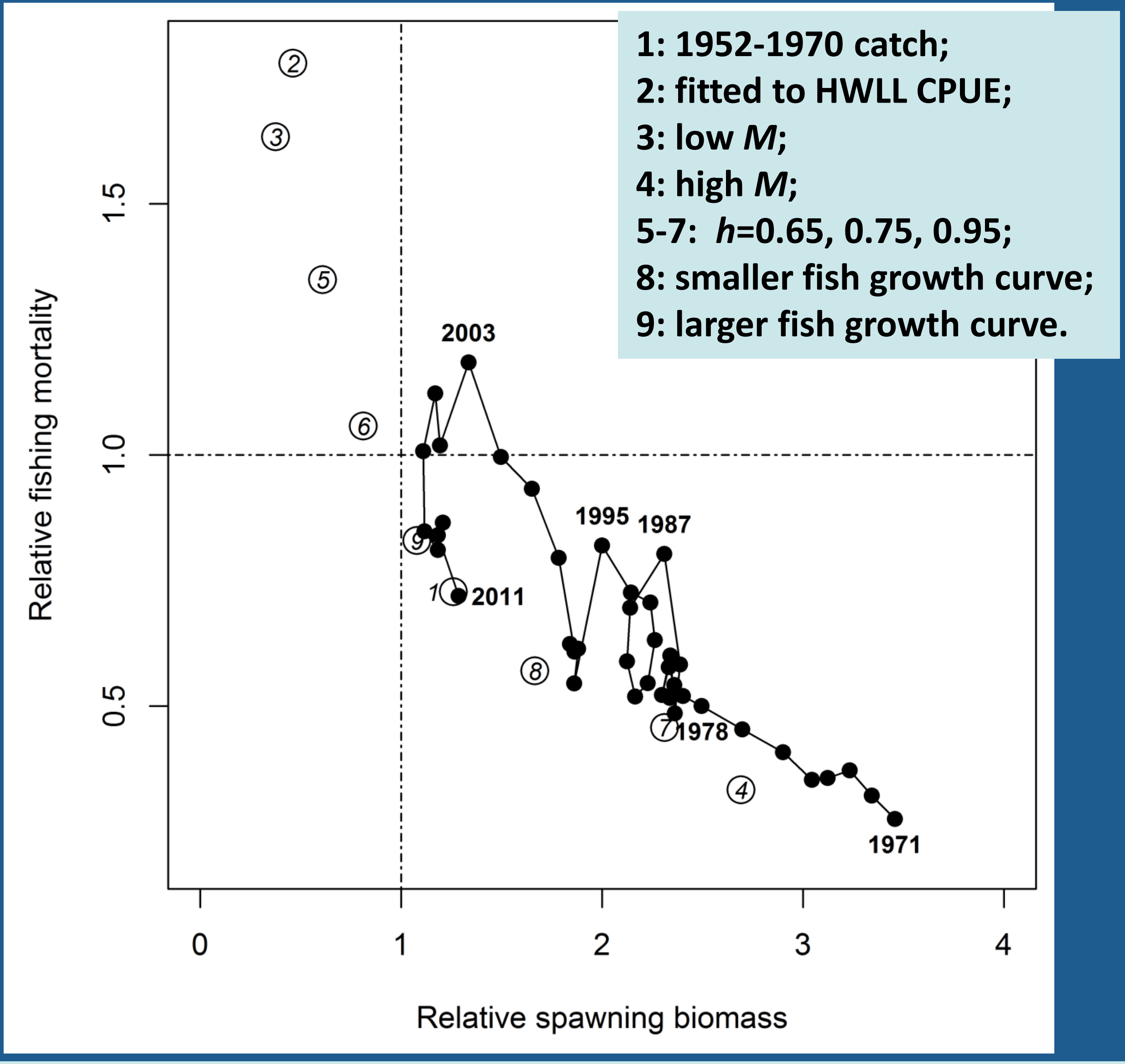
- The population is
  - not overfished
  - not experiencing overfishing
  - fully utilized



Impacts of alternative assumptions on stock status

- Alternative M and h had large impacts on stock status (e.g. stock is overfished and experiencing overfishing for scenario 3, 5 or 6);

- Incorporating catch back to 1952 (scenario 1) had little impact.



Stock Assessment Process

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Habitat and environmental information

improves and informs

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1. Fishery-dependent data
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3. Life history information

PROCESS
Population Dynamics (statistical models)

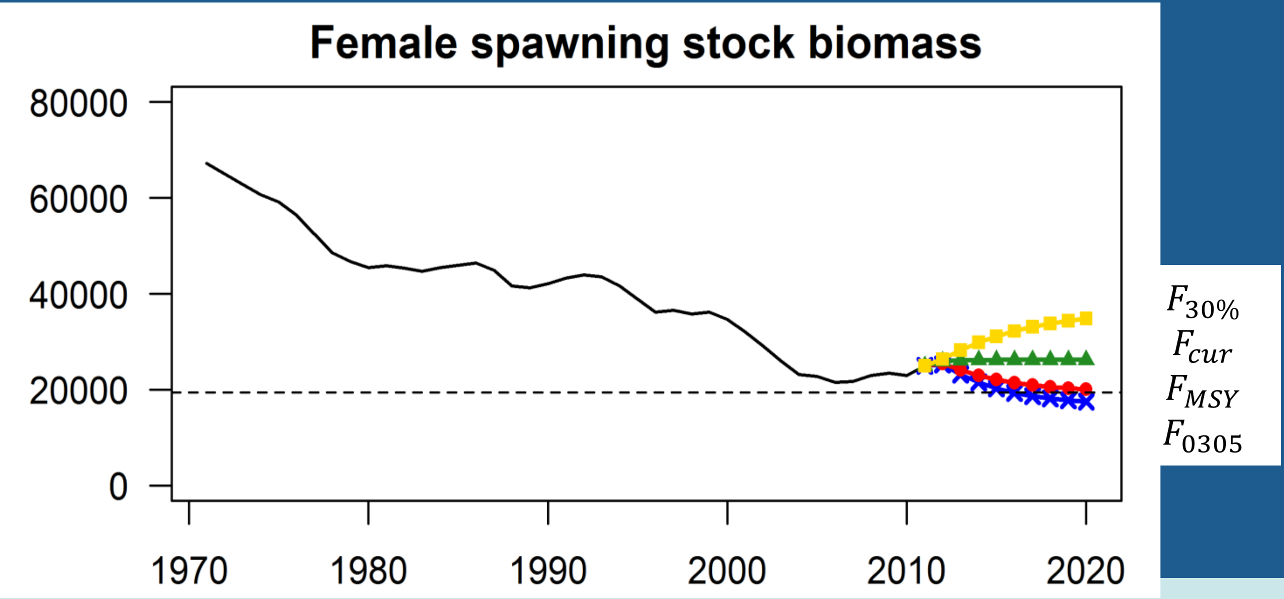
OUTPUT
Stock Trajectory
(Biomass, fishing intensity, recruitment)

OUTPUT
Stock Status
Overfished? Overfishing?

OUTPUT
Forecast (what-if)

Future projections

- When the current level is maintained, the stock is projected to be stable at roughly 26,200 t by 2020.
- If fishing increases to the MSY level, the projected SSB decrease gradually to the MSY level by 2020.
- If fishing increases to the 2003-2005 level, the projected SSB would be below SB at MSY level by 2015.
- If fishing is reduced to $F_{30\%}$, the projected SSB would gradually increase.



What is best available scientific information on *fishery stock assessment?*

- ✓ Description of model structure and assumptions
- ✓ Provide diagnostics of model fit to data
- ✓ Describe model results including stock status relative to biological reference points
- ✓ Characterize uncertainty in model results including sensitivity analyses for key parameters
- ✓ Provide projections of management actions
- ✓ External reviews (ISC Plenary, WCPFC-SC, CIE)

Things we can control

Strengths

- Meet best available scientific practice with ISC
- Use large-spatial scale fishery-dependent data
- Collaborate among nations and RFMOs
- Model matches data complexity
- Model contains enough process (e.g. sex-specific)
- Develop alternative models

Weaknesses

- No long-term large-scale fishery-independent survey
- Assume known catch
- Missing data for important model processes (e.g. sex-specific catch and size, tagging)
- Ignore regional difference (e.g. growth, CPUE)

SWOT Analysis

Opportunities

- Develop indices from other fisheries (e.g. Korea, China)
- Improve catch reporting (e.g. discards)
- Collect sex-specific size
- Improve understanding of stock structure and life history
- Develop spatial structured model
- Develop international tagging program

Threats

- Lag between last year of data and assessment
- Indices always based on fishery-dependent data
- Management should cover the entire Pacific currently multiple RFMOs (WCPFC, IATTC)

Things we cannot control

Steepness

- Steepness of the stock-recruitment relationship (h) was defined as the fraction of recruitment from a virgin population (R0) when the spawning stock biomass is 20% of its virgin level (SSB0).

- Independent estimates of steepness incorporated biological and ecological characteristic of striped marlin in the western and central North Pacific Ocean (Brodziak 2011) reported that mean h was 0.87±0.05.

- Due to the fast-growing characteristic on the early life history stages for both striped marlin and blue marlin, a fixed value at 0.87 was borrowed from striped marlin.

Reference points

Reference point	Estimate
$F_{2009\text{-}2011}$ (age 2+)	0.26
$SPR_{2009\text{-}2011}$	0.23
SSB_{2011}	24990 t
F_{MSY} (age 2+)	0.32
$F_{20\%}$ (age 2+)	0.29
SPR_{MSY}	0.18
SSB_{MSY}	19437 t
$SSB_{20\%}$	26324 t
MSY	19459 t

Sensitivity to alternative assumptions

Data

- Include catch for 1952-1970;
- Alternative stock trend for group B;

Biological assumptions

- Natural mortality rate (M):
  - low M schedule with adult M=0.12 females and 0.27 for males;
  - high M schedule with adult M=0.32 females and 0.47 for males;
- Stock-recruitment steepness (h): h=0.65, 0.75, and 0.95;
- Growth curve:
  - Smaller fish: Length at maximum reference age to be L_{max}= 205. Use a growth coefficient K that is consistent with the size-at-age 1 in the base case;
  - Larger fish: Length at maximum reference age to be $\mathrm{L}_{\mathrm{max}}$= 225. Use a growth coefficient K that is consistent with the size-at-age 1 in the base case;
  - Use growth parameters for males from Chang et al. (2013):
- Size-at-50 percent-maturity ($L_{50\%}$): $L_{50\%}$=197.736 cm and $L_{50\%}$=161.784 cm.

Future projections

- Fishing at the current level or at the MSY level should provide an expected safe level of harvest, where the average projected catches for 2012-2020 is close to MSY.